Characterisation of European CO_2 storage

Developing a storage permit: a risk assessment-led characterisation

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Outline

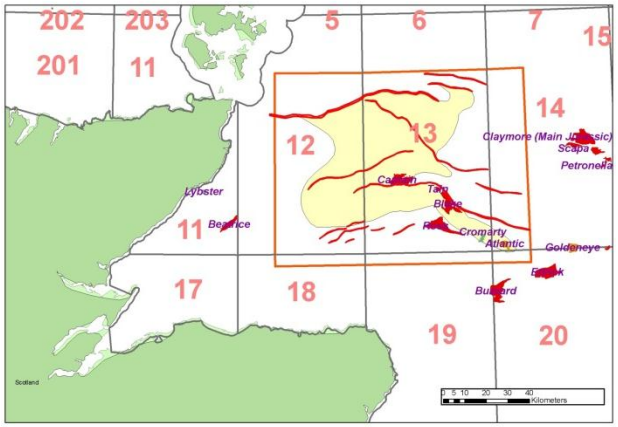
- Introduction to the UK northern North Sea site
- Objectives of the research investigations
- Role of risk assessment-led site characterisation
- Illustrations of risk reduction
- Key learnings
- Remaining issues/challenges
- Recommendations

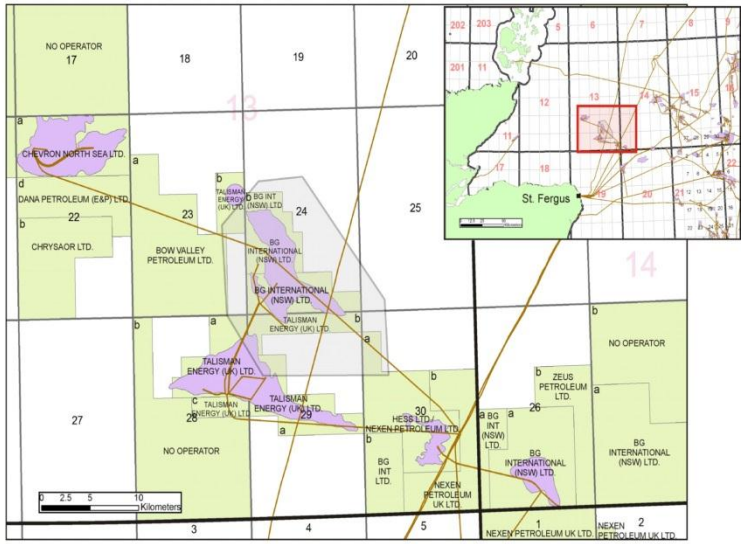
The UK northern North Sea site

- Multi-store site
  - A depleted hydrocarbon field, early storage capability;
  - The host saline aquifer sandstone: greater storage potential, later in the storage cycle.
- Captain Sandstone
  - Identified as feasible for storage
  - Host to hydrocarbon fields
- Project concept
  - CO_2 injection into a depleted hydrocarbon field
  - Up-dip migration beyond the field into the surrounding sandstone

The UK northern North Sea site

- Selection of the hydrocarbon field component
  - Four fields within area of study hosted in Captain Sandstone: Blake Oil Field
  - Meet geological criteria, >800 m depth
  - Sufficiently large estimated storage capacity, >20 Mt CO_2
  - Data available for project
    - High quality, 3D seismic survey
    - Abundance, 36 well penetrations
    - Accessible, publicly available
    - Within the resources of a research project





Objective of the UK multi-store site characterisation

- Evaluate a storage site that combines a hydrocarbon field and a saline aquifer sandstone
- Test an injection strategy to *maximise* the capacity at the site appropriate for commercial-scale storage
- Investigate the relationship between the predicted performance of the storage site and adjacent hydrocarbon fields
- Undertake site characterisation sufficient to inform a 'dry-run' storage permit application

Characterisation for a ‘dry-run’ storage permit application

- Demonstrate understanding of the site for a CO_2 storage permit
- Competent Authority must be satisfied that:
  - Permit applicant has sufficient understanding of the site
  - Proposed site operation will securely contain CO_2
- Application must comply with requirements of EC Directive
- Develop ‘dry-run’ storage permit application, as far as possible, in SiteChar

Scope of the ‘dry-run’ storage permit

- SiteChar is a research project, some components are not developed
  - Environmental Impact Assessment, Reporting Plan, Details of Financial Security, Reporting Plan
- The storage project, though a feasible realistic target for future storage, is a concept:
  - Freedom to explore more challenging aspects of site characterisation and storage permit application than actual demonstration projects in the near-future
  - Reduces the risks associated with developing ‘dry-run’ storage permit applications and allows us to ‘learn by doing’
  - Very resource-constrained and recognise the limitations on the depth of the characterisation and associated storage permit application

Storage permit required components

- Components developed for SiteChar UK North Sea site are determined or informed by risk assessment
- Required components determined by risk assessment
  - Project description (injection strategy, site design & storage performance forecast)
  - Site description
- Informed by results of risk assessment
  - Preventative Measures Plan
  - Monitoring Plan
  - Corrective Measures Plan
  - Post Closure Plan

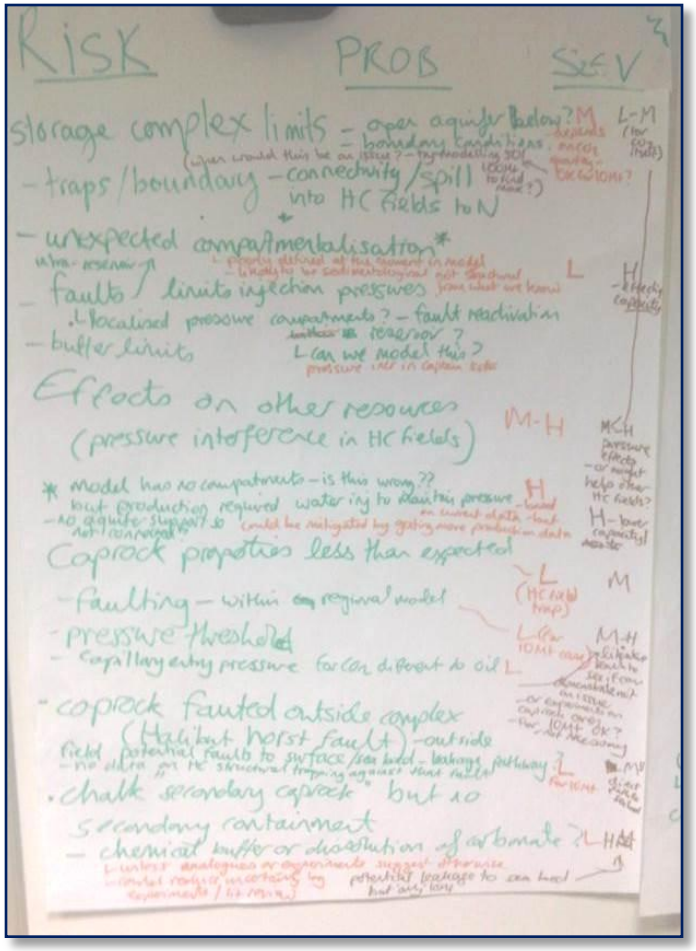
Role of risk assessment in site characterisation

- Site characterisation is about understanding the risks to secure containment of CO_2 at a specific site
- Characterisation is led by risk assessment to
  - anticipate risks,
  - reduce risks
  - mitigate risks
  - monitor unmitigated risks
- Determines what site characterisation activities are needed
- Ensures resources, time and effort are focused to meet the objective

Risk-led characterisation, UK North Sea site

Risk Assessment workshop

- First project activity
- Participation by all experts including technical and non-technical
- ‘Brainstorming’
- Anticipate risks from existing knowledge and expertise
- Initial assignment of probability of a risk occurring
- Initial assignment of likely severity of consequence if a risk does occur



Risk-led characterisation – risk register

- Initial risk register (list of 79 risks)
- Each described and categorised,
  - 12 categories
  - 5 overarching risks
- Ranked by probability & severity
- Highest ranked risk addressed by SiteChar researchers
  - Containment risk
  - Adverse effect on other resources

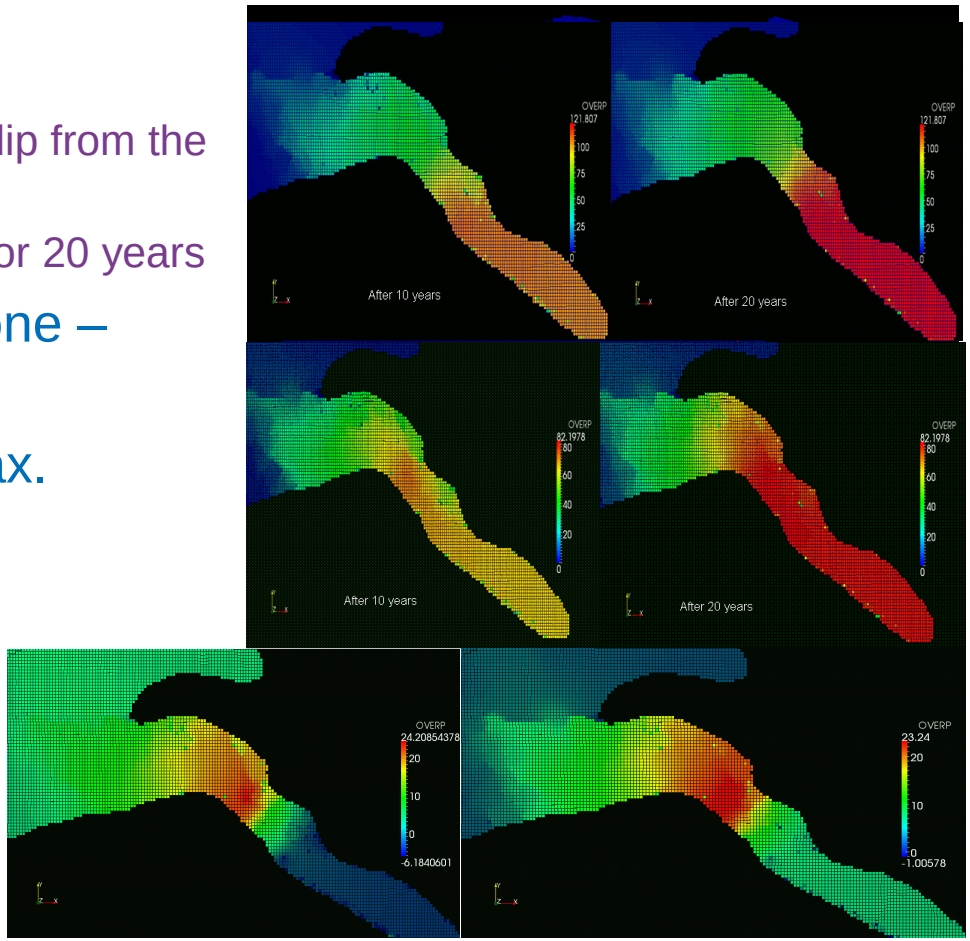
Containment risks	Migration / leakage of injected CO_2
	Loss of injected CO_2 to biosphere
	Displacement or alteration of brines
Adverse effect on other resources	Hydrocarbon fields
	Others
Reduced technical performance	Reduced Injectivity
	Reduced capacity
Monitoring / Regulatory	Monitoring issues
	Regulatory issues
Economic / Environmental	Socio-economic
	Storage costs
	Environmental

Containment risk due to fracturing

- Anticipate risk
  - Risk of fracture of the cap rock that contains the CO_2
  - Increased pressure due to injection exceeds the fracture pressure threshold of the sealing rocks
- Risk reduction – re-evaluation of risk in SiteChar
  - Geomechanical modelling and failure analysis
  - Evaluation of current stress regime at nearby field
  - Prediction of maximum allowable pressure increase
- Risk mitigation
  - Apply the maximum allowable pressure increase (75 to 80 bar) as a constraint for the injection strategy at the site.

Investigation of injection strategy to ensure containment

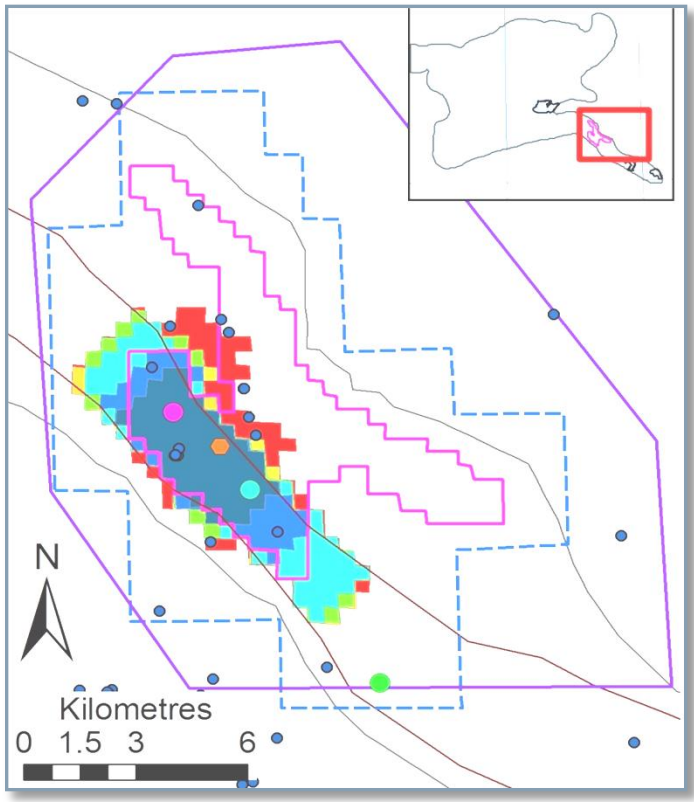
- Two well positions investigated:
  - Within the Blake Field
  - Within the Captain Sandstone down-dip from the field
  - Injection simulated for 5 Mt per year for 20 years
- Injection into the Captain Sandstone – max. pressure increase **122 bar**
- Injection into the Blake Field – max. pressure increase **82 bar**
- Simultaneous injection into the Blake Field and water production from the Captain Sandstone – max. pressure increase **23 bar** (~50 bar less than allowed pressure)

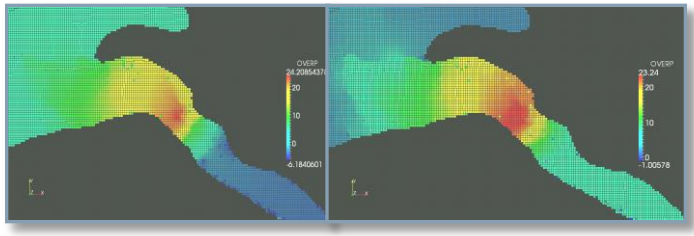


- SiteChar concept is to *maximise* storage capacity; further modelling would reduce and optimise injection rate to manage pressure

Adverse effect on other resources

- Anticipated risk
  - CO_2 migrating to other fields
  - Pressure interference with other fields
- Risk reduction in SiteChar
  - Mapping of CO_2 plume migration
  - Modelling pressure increase ‘footprint’
- Risk mitigation
  - Maximum plume extent, over 1000 years, within immediate vicinity of Blake Field
  - Little pressure change in Captain Field
  - Initial pressure drop in Cromarty and Atlantic then gradual increase to ~10 bar overpressure
  - Additional modelling could further minimise pressure impact





Conclusions

- A first-pass ‘dry-run’ storage permit application has been prepared for a storage site in the UK North Sea
- Risk assessment-led process was successfully followed to reduce risks for containment of CO_2
- In the multi-store site - injection into the hydrocarbon field component produced lower pressures than injection into the saline aquifer sandstone
- Simulation of commercial-scale storage, injection of 100 Mt CO_2 over 20 years
- Injected CO_2 predicted to stay in vicinity of Blake Field
- Pressure relief by water production maximises storage and ensures site integrity is maintained
- Pressure impact on adjacent fields is minimal or within 10 bar

Key learnings from the SiteChar experience

- A first-pass storage permit can be prepared from publicly available data
- ‘Pre-characterisation’ of a site highlights additional investigations and targets information and activities needed
- Even where there is abundant site-specific data, additional information will always be a sought
- Greater anticipation of risks and alternative site parameters will be required where data is sparse
- Pressure footprint and pressure management is a key issue in an area with other users of the pore space

Remaining issues/Challenges

- First iteration of risk reduction activities at pre-characterisation stage has reduced risk and uncertainties; many further iterations of risk reduction and risk reassessment will be needed for storage permit
- UK multi-store site concept is to maximise storage capacity; not addressed minimisation of project cost or optimisation of the injection strategy to manage pressure
- Pressure relief by water production from aquifer component; how would the environmental standards for hydrocarbon and what would the cost implication be to a storage project

Recommendations

- Make readily available data required for storage site characterisation
- Risk assessment should lead site characterisation from the very start
- Successful multi-disciplinary characterisation requires very close integration of all investigations
- The implications of emerging characterisation results in one discipline must be considered by all other disciplines
- Expect the project concept to evolve, reinforcing the need for close communication between disciplines, and anticipate revised planning of site characterisation activities.

Acknowledgments

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